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ABSTRACT

The Zimbabwe Secondary School Science Project (ZIM-SCI) developed student study guides, corresponding teaching guides, and science kits for a low-cost science course which could be taught during the first 2 years of secondary school without the aid of qualified teachers and conventional laboratories. This ZIM-SCI study guide presents activities and experiments for a three-part unit in which students investigate various aspects of force. Part 1 focuses on: familiar forces and the changes they cause; magnitude and direction of force; opposing and balancing forces; unbalanced forces (leading to the concept of acceleration); momentum; magnetic and electrostatic forces; and gravity. Part 2 focuses on measurement of forces; instruments used to measure forces; and friction. Part 3 concentrates on the concept of work, leading to definitions for work and for joule as the unit of energy. Machines are introduced as devices which make work "easier," laying the foundation for introducing the concept of "power" and definition of a Watt. A simple experiment measuring muscle power and a comparison of power available from various common energy converters concludes the unit. Information is provided throughout the unit to help students understand the scientific concepts behind the activities and experiments. (JN)

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ZIM-SCI

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

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STUDY GUIDE UNIT H1

Forces in Action

SE 043 853

UNIVERSITY OF ZIMBABWE
AND MINISTRY OF EDUCATION AND CULTURE

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April 1983

ZIM-SCI

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

GENERAL SCIENCE

STUDENTS: Please read this carefully. It will help you.

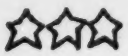
How you will study

This Study Guide comes to you with a kit of apparatus. Both things are part of a study programme leading you to an understanding of aspects of science. In this course you will be carrying out experiments. The Study Guide will help you to understand the scientific principles behind the experiments.

Your work should be done as you are instructed, either by the teacher or the Study Guide.

To help you to see quickly what you must do, the Study Guide uses these symbols:

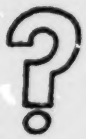
for "Read and revise your notes and Study Guide"



for "Take note of an important point that you should learn"

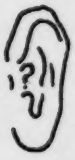
for "Summary. This is to help you to go over what you have learned"

for "Experiment"
When you see this sign, read the instructions carefully from beginning to end before you start to do the experiment.



for "How much do you know?"
This is for you, to help you to test whether you are remembering what is important.

for "Written work"
This is when you must answer questions in writing.



for "Listen to the teacher and do exactly what the teacher tells you to do"

for "Activity"
This symbol will appear whenever you are asked to do something without your apparatus.

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Aims of this Unit

At the end of this unit you should be able to :

1. Explain the connection between force and energy
2. Describe some ways in which forces act.
3. Name some substances which are elastic.
4. Name three forces which act at a distance.
5. Calibrate and use a force meter to measure forces.
6. Define the unit of force.
7. State the force of gravity.
8. Describe some advantages and disadvantages of friction.
9. Define the unit of work.
10. Describe some machines which make work easier.
11. Define the unit of power.
12. Explain why machines are useful.

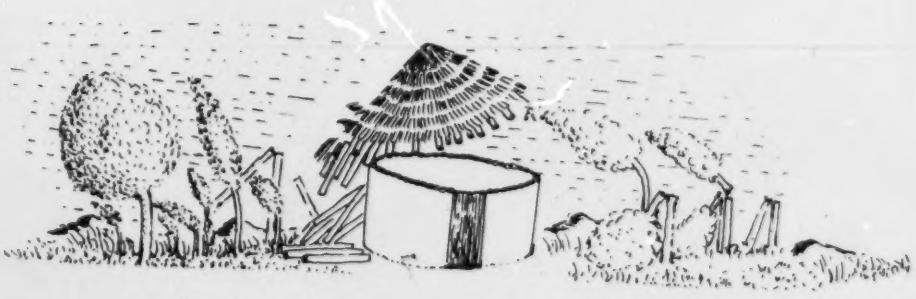
PART I FINDING OUT ABOUT FORCES

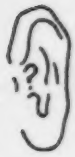
In Unit B you learnt about energy. You noticed that it was not possible to hold energy. You could only tell its presence when it made things happen. FORCE is like energy in two ways. We cannot touch it and we can only tell its presence when it is at work.

Perhaps you have heard the word force being used in different ways. For instance, you force a hoe into a handle. This is one way the word is used. Your teacher forces you to do homework is another way the word is used. You will notice that in both examples given, strength is involved. You use your strength to force a hoe into a handle. Your teacher uses his strength as a teacher to make you do homework.

In the first use of the word force a lot of energy is needed. When scientists think about a force this is the kind they mean!

Perhaps you have seen forces in action in your everyday life. You will notice that among the forces you have seen some are quite strong and can move big things. A strong wind can have enough force to blow off the roof of a hut. It can also bend and even break big trees. Sometimes forces can be quite small. Only a small force is required to move the leaves on a tree.





It will be interesting to think of how often you use forces to move different things each day. Your teacher will discuss this with you now.

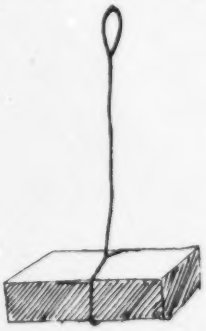
To help you understand more about forces, you will now do some simple experiments.

EXPERIMENT 1 : Lifting a brick or a stone

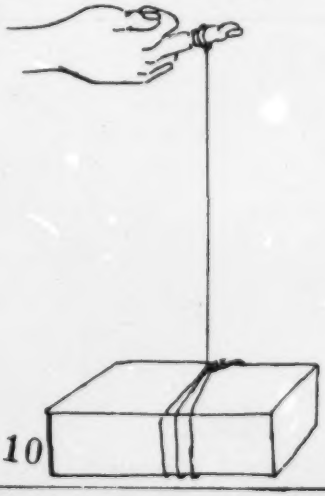
You will need:

a brick (or stone the size of a brick)
a piece of string about 1 metre long
(the string must be strong enough to lift a brick)- a strong piece of wire of the same length will do)

Now tie one end of the string around the brick so that the brick does not fall out of the string easily. Then make a loop, the size of your longest finger, at the other end of the string. The brick and string must now look like this.



Stand up and stretch one arm in front of you. Your partner will slip the string over your longest finger. Try to hold your finger still. Then move your finger slowly up. Move it slowly down, slowly up again and then down. Now let your partner do the same.



How did your arm feel as you moved the brick up and down with your finger? Did your arm feel tired? Was a force involved? Where do you think the force came from?

EXPERIMENT 2 : Pulling things

Your teacher will give you a few things to try and pull. From the things your teacher has given you, pick up one rubber band and pull it between your fingers.

How does it feel as you pull the rubber band? Now pull it harder until it no longer stretches. Then pull two rubber bands together side by side. How does it feel this time? Can you stretch the rubber bands further? Observe carefully what happened to the rubber bands.

What happened to the length of the rubber band as you pulled it?

What happened to the shape?

Could you go on stretching the band?

As you stretched the band, how much force did you have to use to do this?

What happened to the force you used as you stretched the band further?

Did the band get harder to stretch as you stretched it further?

Now put the rubber bands away.

In the rubber band experiment you probably noticed that the shape of the band changed. The band became longer and thinner as you stretched it. Perhaps you discovered too that the more you stretched the band the harder you had to pull. It became harder to stretch the band more. You discovered also that you had to use more force to stretch two bands. As you pulled the rubber band you probably felt the rubber band pushing your fingers together. So two forces were at work here. Your 'finger' force pulling the band and the 'rubber' force pushing your fingers back together. The two forces were acting in opposite directions. Your finger force was pulling the band in one direction and the rubber force pushing your fingers in the opposite direction. Push and pull forces always act in pairs in opposite directions.

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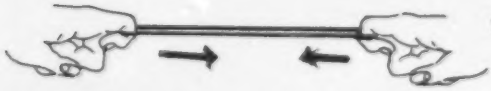
Sometimes scientists use arrows like this ⟶ to show the directions of forces. The directions of your 'finger force' and 'rubber band force' can be shown like this.

finger force



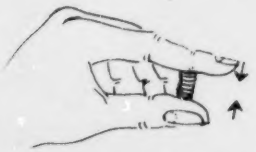
rubber band force

You noticed too that you could hold the rubber band stretched. When this happened it meant that your finger force was equal to the rubber force. The two forces had balanced.

☆☆☆

Do you remember what happened to the shape of the rubber band when the force stretching it was removed? Did the rubber band stay long and thin? In fact, it returned to its shape. Substances which return to their shape after stretching are said to be elastic or springy.

Now pick up a spring from the things your teacher has given you. Try to pull it as you did with the rubber band. Is it elastic? Is it easier to stretch than the rubber band? Try to squeeze the spring between your fingers.



How does it feel? How many forces are at work here? Count them.

Now try to pull, squeeze, twist the rest of the materials your teacher has given you and then answer Exercise 1 in your books.

You have looked at various materials which could be stretched, squeezed and twisted using forces from your hands. Remember the syringe experiment in Unit C2? It will be interesting to find out more about how air behaves when it is pulled and squeezed.

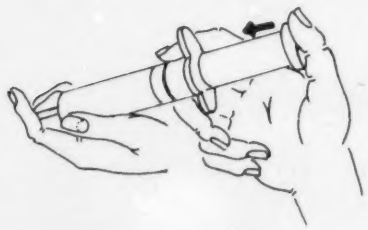
EXPERIMENT 3 : Squeezing and pulling air

You will need:

a 10ml syringe for this experiment

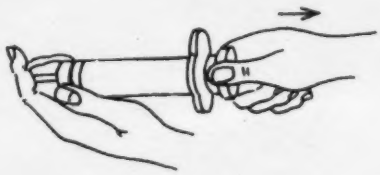
Pull the syringe handle until it is about three quarters up the syringe. Then close the other end of the syringe by pressing it hard against your finger.

Now push the handle down slowly with your thumb.



What happens as you push the handle down? How does it feel as you push the handle? Now stop pushing the handle. What happens to the handle? Push the handle down again, harder this time. Can you push the handle right down to the bottom of the syringe? How far down did you have to push before it was difficult to push? How many forces are in action?

Now push the handle right down to the bottom of the syringe without closing its small end. When you have done this, close the small end again as you did before and pull the handle slowly. How does it feel pulling the handle this time?



What happens to the handle when you stop pulling it? Can you explain this observation? Remember your work about air pressure in Unit C2! Write a paragraph in your notebook trying to explain what happens. (Exercise 2)

You noticed that the further down you pushed the handle the harder you had to push to make it go further. You had to use more force. As you pushed the handle the air gave you the feeling of a squeezed spring and when you stopped pushing the handle it was pushed back without your help. This means then that air, like a spring, is elastic. You also felt its springyness when you pulled the syringe handle with its small end closed. Were push and pull forces involved in both parts of the experiment? Where did the push force come from? Where did the pull force come from? When did the forces balance?

Your teacher will discuss these questions with you now. When you have finished answer Exercise 3.

MORE ABOUT FORCES

You have seen that forces act on things when they are pulled or pushed. Now you are going to investigate balancing forces.

EXPERIMENT 4 : Balancing forces

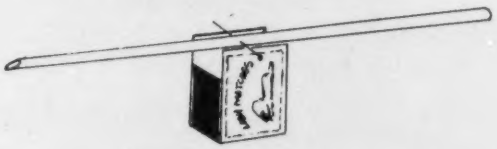
You will need:

- a drinking straw
- a pin
- 4 paper clips
- an empty match box

Find the centre of the drinking straw by measuring it and then stick a pin through the centre.

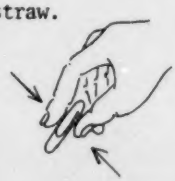
Now cut off part of the brown sides of the match box. Your box should now look like this.

Your straw should swing freely when it is placed on the match box. If you push up on one end of the straw gently can you feel a very small force pulling down against your finger? What is this force?

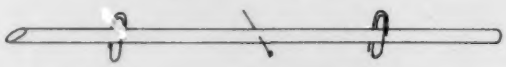


(If you kept the box you used in A1, Experiment 10, you should use it and not cut another one.)

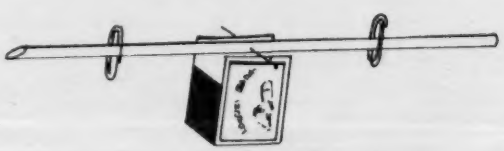
Squeeze the ends of two clips as shown so that each fits tightly over the straw.



Now slide the two clips over the straw, so that one clip is on each side of the pin.



Place the straw on the match box.



Is the straw level? If it is not, move the clips on the straw. You may have to move the clips along the straw several times to make it level. When the straw is level, what does this tell you about forces acting? Try putting two clips on one side and one on the other. Make the straw balance again. The straw must be level in the end.

Now answer Exercise 4.

WHAT HAPPENS WHEN FORCES DO NOT BALANCE?

Activity 2 : A force game

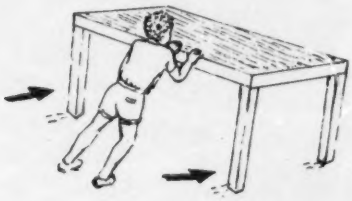
In this game you and your partner sit on opposite sides of your desk facing each other. Rest your right elbows on the desk and join your right hands.

Wait until everybody is ready and when your teacher says 'GO' you and your partner start pushing. Do not start pushing before your teacher says go, otherwise the game is unfair. You must try to make your partner's hand touch the desk. As you push keep your elbows on the table all the time!

Who was defeated in the game? When did the forces balance? Where did the forces come from? Who produced a bigger force? What happened when the forces became unbalanced? Can you think of another interesting game on forces?

Activity 3 · Pushing your desk

Try to push your desk with one finger. What happens? How many forces are at work as you try to push? Push the desk with both hands and harder this time. What happens to the desk this time?

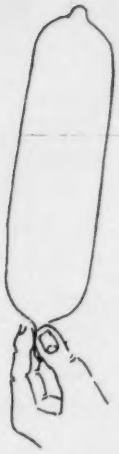


You probably felt the desk pushing your finger as you tried to push it the first time. Perhaps when you pushed the desk the second time it moved. What caused this to happen? Well, as in the force game, forces did not balance! One force became greater than the other. Your force became greater than the pushing desk force. If you pushed the desk even harder it would move even faster. Here are two simple experiments in which forces make things move.

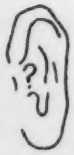
EXPERIMENT 5 : A moving balloon

You will need a long balloon.

Blow air into the long balloon until it is about as long as a page in your study guide. Then hold the end of the balloon between your fingers so that the air does not come out and the balloon points up.



Then let the balloon go! What happened to the balloon when you let the air out? Was force involved? Where did the force come from? Discuss this with your teacher. When you have finished your discussion be ready to do another interesting experiment on forces.

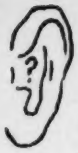


EXPERIMENT 6 : Match experiment

You will need:

- a match stick
- a piece of aluminium foil about 2cm x 2cm
- your evaporating dish
- your burner and stand

Take out a match stick from the box and wrap it in the aluminium foil. Now place your evaporating dish on a stand and heat it using your burner. Continue heating the dish until it is very hot, then remove the burner and quickly place the match stick wrapped in foil in the dish and observe what happens.



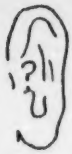
Was a force involved? Where do you think the force came from? Your teacher will discuss your observations with you.

These two experiments show you the kind of forces which send rockets into the air and have taken man to the moon!

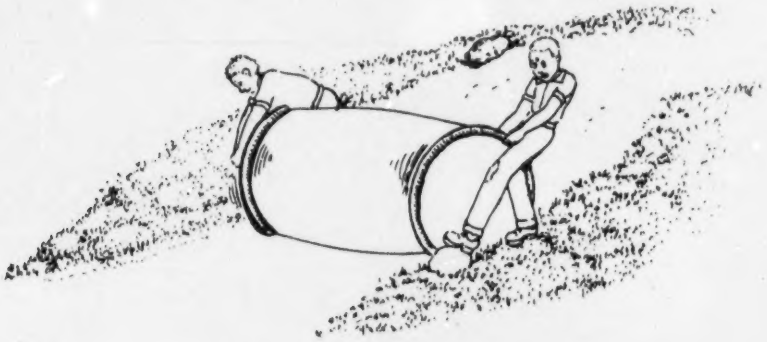
Sometimes forces make things move faster and faster. Perhaps you have seen a dog chasing a hare.

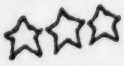
The dog and the hare run faster and faster because their legs are putting a lot of force onto the ground.

You have been learning about forces and how they make things move, but can you think of a way of <u>stopping</u> moving things once they have started moving? How, for instance, could you have stopped the moving balloon in Experiment 5? Could you have done it without using force? To investigate this you might like to start with your boiling tin. Take it out of your kit now and roll it on your desk. Remember, you have made it roll with the force from your fingers. In how many ways can you get the tin to stop? You will notice that whatever way you use to stop the tin a force is needed. Try to work out where the stopping force comes from. Which is the best way of stopping the tin? Where would you apply the force to stop the tin quickly? Try stopping it near the end, what happens? Does it stop quickly? Try the middle - which position stops it quicker?



Your teacher will discuss these observations with you. Quite often it becomes difficult to stop some things once they have started to move. For instance, it would require force from several people to stop a drum of water once it has started rolling.



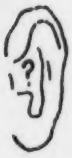


Of course a thing needs a force to get it moving, but once it is moving it needs another force to stop it! The faster the thing moves the more difficult it is to stop it. The faster you cycle the more difficult it is for you to stop.

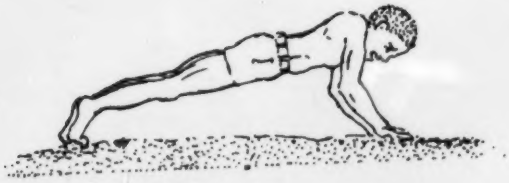
Now do Exercise 5.

FORCES AT A DISTANCE

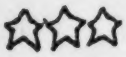
The forces you have been looking at so far move or stop things by touching them. You moved your desk by pushing it and you stopped a rolling tin by holding it. But are there some forces which can move things without touching them? To investigate this, hold your pencil above the floor and then let it drop. What happens to the pencil? Does it move? Is a force involved in moving it? Do you remember what this force is called? Think back to Unit A1. Perhaps you will feel the same force yourself if you do a 'pressing up' exercise. You will need to go outside your classroom to do it. Your teacher will tell you what to do.



Could you push up without using a force? You probably noticed that you had to use forces inside your body to push up. You can imagine what your muscles were doing inside you.



They were pulling one after another as you moved and raised the different parts of your body. Can you think of what made it difficult for you to do this? Did you feel the earth pulling you down as you tried to push up? The force with which the earth pulls things is called the <u>force of gravity</u>. This force is often called WEIGHT. You have probably heard people talk about the weight of a baby or bag of mealies. What they are <u>thinking</u> about is how much <u>mass</u> the baby or bag of mealies has. This is a common confusion which you as Zim-Scientists will not make!



Mass is not the same thing as WEIGHT. It is very important that you should be able to tell the difference between the two. The mass of a body tells us how much material is in that body. Mass is measured in kilograms. The WEIGHT of a thing is the FORCE with which the earth pulls on that thing. Weight is a force.

MORE FORCES AT A DISTANCE

EXPERIMENT 7 : What a magnet does to iron filings

You will need:

a few iron filings
your magnet
a piece of paper

Collect the iron filings from your teacher with a piece of paper. Then move your magnet towards the iron filings slowly. Please do not touch your iron filings with your magnet.

What happens to the iron filings as you move the magnet nearer the filings? Do you think a force is involved? Where do you think the force is coming from? Now collect all the iron filings and give them back to your teacher. Don't forget to remove the iron filings sticking on the magnet!

You observed the iron filings moving towards the magnet. You did not have to touch them with a magnet to make them move. This force is often called a MAGNETIC FORCE. Like the force of gravity magnetic force can work at a distance.

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Activity 4

Here is another force which works at a distance. Try rubbing your ball point pen on your shirt, then place it near a pile of small pieces of paper. What happens to the pieces of paper?

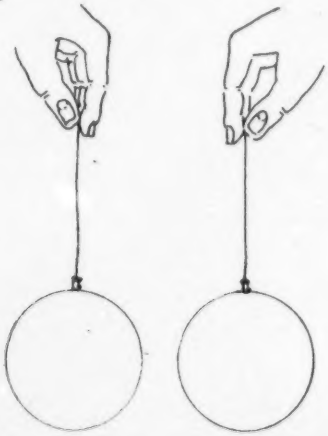
Try rubbing your polythene stirring rod or a plastic ruler and placing it just above the pile of small pieces of paper. How do the small pieces behave? Do you think a force is involved here? How can you tell that a force is involved? Where do you think the force is coming from? Discuss these questions with your partner. When you have finished your discussion, your teacher will give you two balloons to try another interesting experiment.

EXPERIMENT 8 : Balloon experiment

You will need:

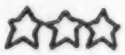
two balloons
two pieces of thread

Blow some of your air into both balloons until each is about the size of a football. Tie each of the balloons with a piece of thread. Do this well so that the air does not come out. Now rub both balloons on your clothing and hold the balloons so that they hang about 10cm apart.



Observe what happens to the balloons.

What did the balloons do as soon as you let them hang? Do you think a force was involved?



Like the pieces of paper, the balloons moved because there was a force between them. This force made the balloons move without anybody pulling or pushing them. Like the force of gravity this force makes things move without touching them. It may surprise you to learn that this is an ELECTRICAL force.

Now do Exercise 6.

Now Read and Revise, and do "How much do you know?" Part I

How Much do You Know? (Part I)

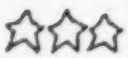
1. When a force is used, _____ is needed.
2. Forces, like energy, cannot be touched, but can be identified by their _____.
3. A force is needed to _____ an object.
4. A force is needed to stop a _____ object. The greater the _____ of an object the greater the _____ needed to stop it.
5. _____ can speed up the movement of objects.
6. A force has a _____ which can be represented by an arrow.
7. Push and pull _____ act in pairs in _____ directions.
8. (Push and pull) _____ may change the shape of an object.
9. Substances which return to their shape after stretching or squeezing are said to be _____.
10. Air is an _____ substance, so is _____ and a _____.
11. Equal forces acting in opposite directions are _____ balanced forces.
12. When one force is greater than another, the forces do not _____.

13. The force with which the earth pulls things is called the force of _____.
14. Weight is a force. The weight of something is the force with which the earth _____ on that thing.
15. Two forces which act at a distance are _____ and _____. They make things move without anything touching them.

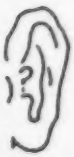
PART II MEASURING FORCES

HOW BIG IS A FORCE?

You have now learnt about many kinds of forces. You have seen that forces can act sideways, upwards as well as downwards and even at a distance. Sometimes it is necessary to know how big or small forces are and to compare them. To be able to do this you need to measure the forces. Since you cannot see a force you cannot measure the size of a force in the way you measure the length of a line. To measure the size of forces you must measure their effect on things.



You have learnt that a measuring instrument is often called a meter, e.g. thermometer or speedometer The instrument which measures force is called a FORCEMETER.



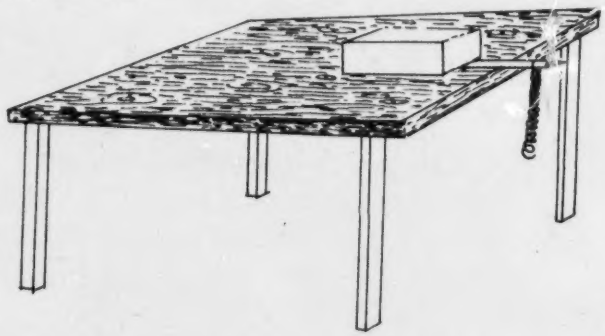
You can now investigate a forcemeter. Before you begin, try to think about how you can measure the pushing or pulling force of one finger. Discuss this with your teacher.

EXPERIMENT 9 : How a forcemeter works

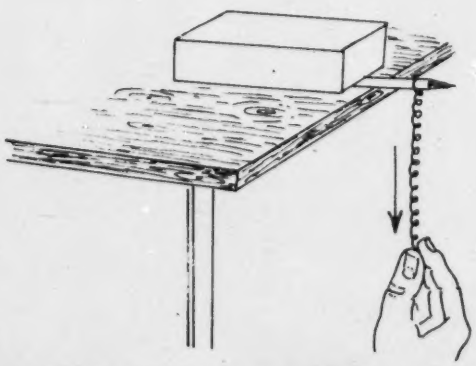
You will need:

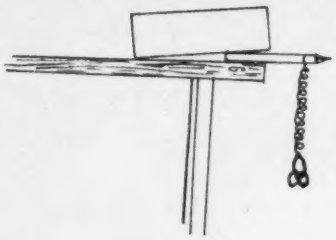
- your pencil or ball point pen
- a spring
- a piece of thread
- a ruler
- a brick
- 5g masses

Tie the spring onto your pencil with thread and place the pencil under a brick. Do this near the edge of your desk.



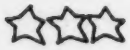
Now pull on the spring. How far does it stretch? How much stretch is done by one finger force? Do you think this is a good way of measuring forces accurately? What else could be used to stretch the spring? Put two 5g masses onto the end of the spring. You may have to use a thread to do this.



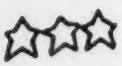


What happens to the length of spring? Will another equal mass stretch it by the same amount? Now put another two masses on the spring. Then measure the amount of stretch with a ruler. Record your measurements

N.B.
The force pulling the spring is the force of gravity acting on the 5g masses. In other words the weight of the 5g masses is pulling the spring.

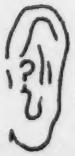


In the experiment you should have noticed that the more masses you added the more the spring stretched. You should have noticed too that the spring stretched by the same amount each time you added the same weight. By measuring the new length of the spring each time you probably began to see how a force could be measured. But before the force measurement can really be of use we must decide on the standard unit of force. This unit is called a Newton, sometimes written as "N".



It is the unit of ALL forces including weight. The force of gravity (weight) on a mass of 1 kg is about 10 Newtons. Can you work out the force of gravity on each of your 5g masses. The forcemeter must be calibrated in Newtons.

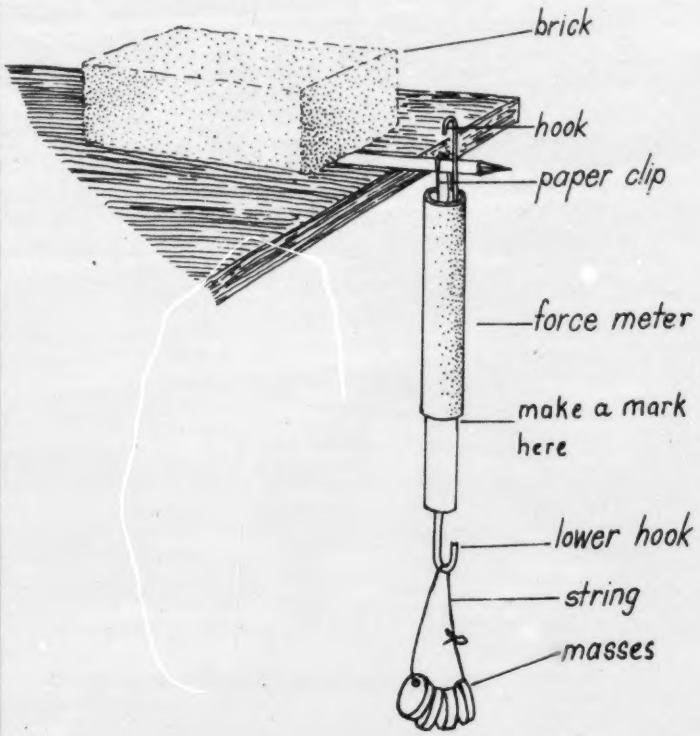
Since you now have enough ideas to make a forcemeter, your teacher will give you an instrument which you can use to measure the sizes of forces but it needs a scale! Look at it carefully and think about how you can use it to measure a pulling or pushing force. Think carefully about this problem with your partner. Your teacher will probably want to share your ideas with you.



Experiment 10 : Calibrating the Forcemeter

You will need :

Your pencil or ball point pen
the forcemeter
a paper clip
a brick
20 5g disc masses
20 cm of string



Fasten the paper clip onto the pin at the top of the forcemeter (this is the one that holds the spring in). Then hang the forcemeter from your pencil or your ballpoint pen using the paper clip (see diagram). First make a mark on the wooden part of the forcemeter using the edge of the plastic as a guide. This is your "zero" mark. Then thread on 5g mass onto the string. Tie a

loose knot and then hang the mass by the string on the bottom of the forcemeter. Mark this point on the wooden part. Now repeat the procedure adding one 5g mass each time and marking each point on the wooden part of the forcemeter. Do this until you have 20 of the 5 g masses hanging from the forcemeter.

Write up this experiment in your notebook

Now that you have calibrated your forcemeter you can use it to measure some forces.

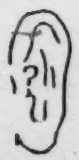
EXPERIMENT 11 : Measuring pulling and pushing forces

For this experiment you will need some small things you can push or pull with your forcemeter. Among these you may include your boiling tin, plastic cup, etc. But before you start copy the table your teacher has drawn on the blackboard into your exercise books.

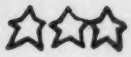
If you have decided to start with your burner, place it on your desk. Pull it and push it with your forcemeter. Record the force needed in the table. Do the same with four or five things you decided to pull or push. Find which one of the things needs the greatest force to move it. When you have completed your table answer Exercise 7 in your exercise book

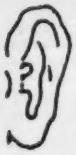
Activity 5

Your teacher will give you your basic kit. Carefully take out all the apparatus and put in a safe place for this lesson.



Now use a push force to make the box move across the desk. Watch it very carefully. Does it stop when you stop pushing? Can you describe what happens to the box after you stop pushing? Push the box several times until you are sure of what happens. Now discuss this with your teacher.





When two surfaces rub against each other, a force is produced which makes it difficult for the surfaces to move. This type of force is called FRICTIONAL FORCE. Quite often frictional force is shortened to Friction. Frictional force is in action whenever surfaces rub against each other. Think of examples where you think frictional force may be acting. Tell your teacher when you are ready with your answer.

CAN FRICTIONAL FORCE BE CHANGED?

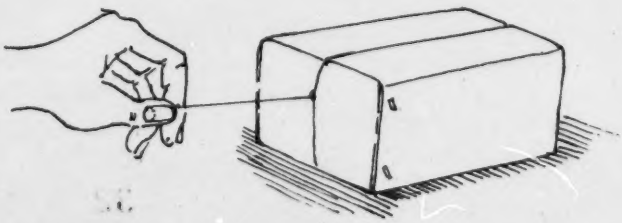
You have seen that frictional force makes it difficult for things to continue moving. So sometimes a lot of energy is required to keep things moving. But is frictional force always the same each time surfaces rub together? To investigate this you will need to move things again.

EXPERIMENT 12 : Investigating frictional force

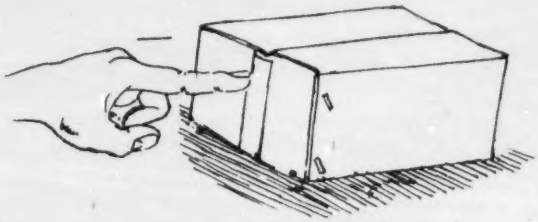
You will need:

- some dry soil
- your empty kit box
- a piece of thread
- two mounting needles
- handlens

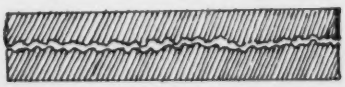
Pour some dry soil into your kit box until it is just about full. (Do not fill it completely. You will not be able to close it if you do this.) Now close the box so that the soil does not come out. Place the box on your desk. Tie a thread round the box and then pull it with your finger.



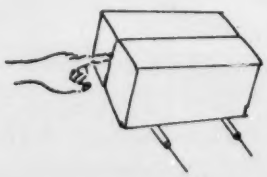
Then push it with your finger. Is the box easier to pull or push? Now place the box on the floor. Push and pull it as before. What happens this time? On which surface is the box easier to pull? On which surface is the frictional force greater?

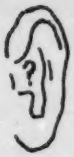


Put your box away and look at the surface of your desk closely. Use your handlens to help you observe. How does it look? Feel the surface with your fingers and run them along the surface. How does the surface feel? Observe the surface of the floor as well with your handlens, then feel it by rubbing your fingers on it. How does it feel? Every surface has bumps and hollows on it. These bumps and hollows can be seen on some surfaces quite clearly. On other surfaces the bumps and hollows can be seen with the help of a handlens. They can be felt with fingers too. Smooth surfaces have smaller bumps and hollows than rough surfaces. When two surfaces rub together these bumps and hollows make it hard for surfaces to move easily on each other.

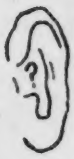


Now place two mounted needles on your desk and then place the kit box on them and pull as you did before.





Is it easier or harder to pull than before? What has happened to frictional forces this time? Discuss these questions with your teacher.



Pour out some of the sand until the box is almost empty. Place it on your desk again and pull. Is it easier to pull now than when it was almost full ? What do you think has happened to the frictional force? Discuss this question with your teacher too.

You felt what happened to frictional force when you pulled and pushed your box on different surfaces. You also felt what happens to it when you changed the weight (force of gravity on the box).

Now you will measure these forces.

EXPERIMENT 13 : Measuring frictional forces with your forcemeter.

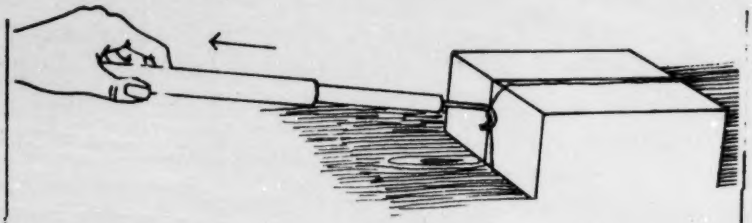
You will need:

- your empty kit box
- some sand
- your plastic cup
- the thread you used in Experiment 12.
- mounted needles

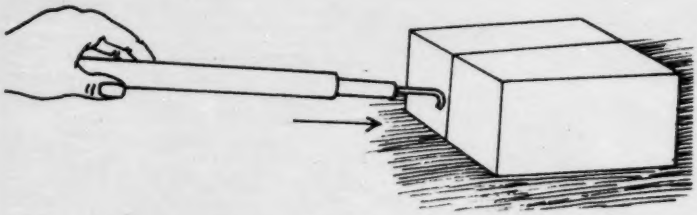
Before you begin this experiment copy into your notebook the table which your teacher has put on the blackboard.

Pour some sand into your plastic cup until it is about a quarter full. Pour this sand into the empty box and place the box on your desk again. Tie the thread around the box again and pull the box using your forcemeter this time.

Look at the reading on the forcemeter as you pull steadily and record this reading in your table.



Now push the box with the forcemeter, note the forcemeter reading as you push and record it in your table.



Now place the box on the table on its side this time. Pull and push it with a forcemeter as you did before and record the readings in your table.

Now repeat the whole experiment on the floor. Record all the readings in your table. When you have done this, place two mounted needles on your desk. Place the box on the mounted needles then pull and push with your forcemeter recording each reading in your table as before. When you have completed your table your teacher will discuss it with you. He will also discuss with you other ways of changing frictional forces between surfaces.

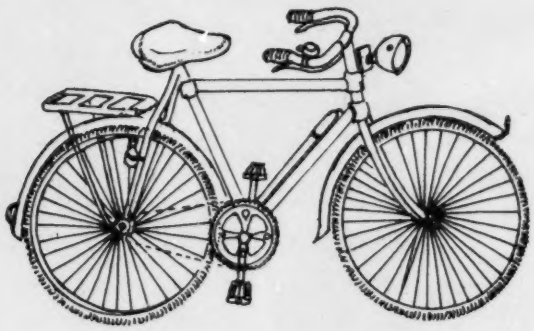
You have seen that frictional forces make it difficult for things to move. What else happens as surfaces rub together? What happens when you rub your hands together for instance? Perhaps you have often done this when your hands feel cold. Try rubbing them together now. Rub them quickly. How does it feel?

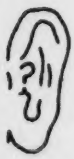
Did you feel your hands getting hot? Heat energy is always produced when surfaces rub together.

WHEN FRICTION IS A NUISANCE

In many machines like motor car engines, metal surfaces rub on each other very fast producing a lot of heat. This heat can easily damage the metal surfaces.

Tyres of motor cars and bicycles wear away as they rub on the ground. So frictional forces do some damage wherever they are in action. In everyday life there are many places where we want to reduce frictional forces. You learnt how frictional forces can be reduced, can you give your teacher a few examples where this should be done? Perhaps you would want to begin with your father's bicycle. To help you think about your father's bicycle, here is a diagram of a bicycle.





Perhaps your teacher can bring a bicycle for you to look at. Examine the bicycle and decide:

(a) where you would expect to find a lot of frictional force;

(b) where it would be necessary to reduce the frictional force;

(c) what things have been used in those parts to reduce friction.

Answer Exercise 8 in your notebooks.

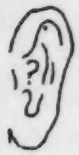
SHOULD FRICTION ALWAYS BE REDUCED?

You now know some ways in which frictional force can be reduced to make surfaces move easily, but should frictional forces always be reduced? Is frictional force always a bad thing? When you examined the bicycle you probably noticed some parts of the bicycle where there was a lot of frictional force. If you did not notice these parts, your teacher will help you to find them.

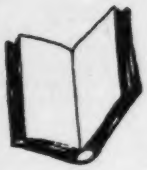
Riding without brakes is dangerous.

Would it be easy for you to cycle on a road which has slippery mud? There would not be enough frictional force between the tyre and soft slippery mud. So it would be quite difficult to cycle on such a road.

To make it easy for cars and bicycles to move even on a road with slippery mud, tyres are made in a special way.

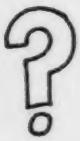


Look carefully at the diagram of a new bicycle tyre and decide how it makes cycling on a slippery road safe.



Now Read and Revise and do

"How much do you know" Part II



HOW MUCH DO YOU KNOW PART II

1. An instrument which measures force is called a _____

2. A forcemeter can be calibrated by _____

3. The standard unit of forces is a _____

4. The force of gravity on a mass of 1 kg is about _____

5. When two _____ rub against each other a frictional _____ is produced.

6. _____ makes it difficult for things to move.

7. Friction forces produce _____ energy when they act.

8. Friction can be reduced by the use of _____

PART III DOING WORK

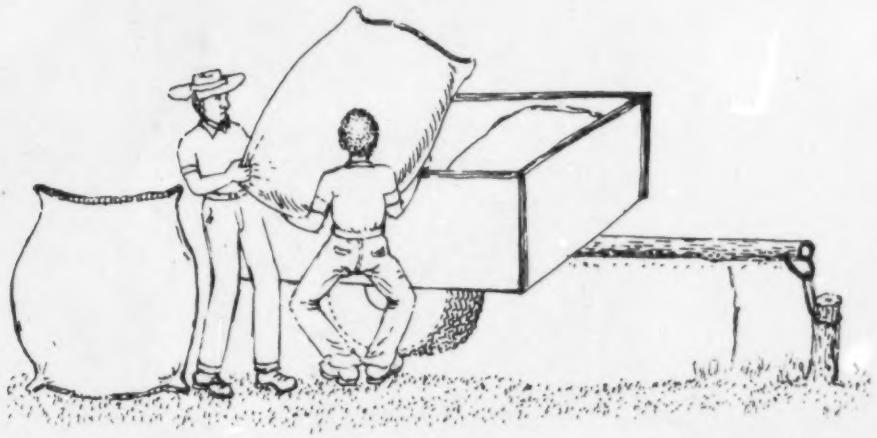
LET US DO SOME WORK

In Unit B you learnt about how chemical energy in the food you eat is converted into other forms of energy. When you lift a bucket of water onto your head you convert the chemical energy in your body to kinetic energy. As you lift the bucket onto your head you convert this kinetic energy into potential energy.

You use more of your energy to lift a heavier bucket. You also need to convert more of your energy to lift the bucket higher. Perhaps you have noticed already that the amount of energy you convert to potential energy of the bucket depends on two things. It depends on the size of force you use to lift the bucket. The energy you convert also depends on the height to which you lift the bucket.

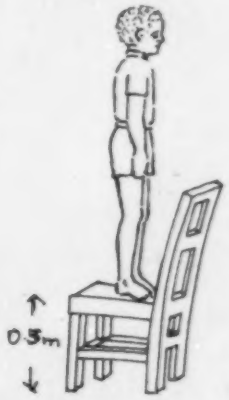
To make this clearer, here is another example.

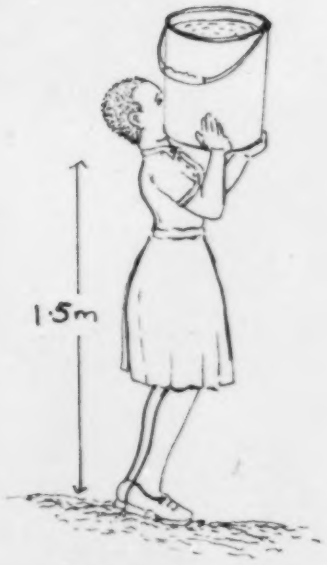
When you do some work like lifting bags of maize into a cart, you also convert some of the chemical energy in your body to potential energy.

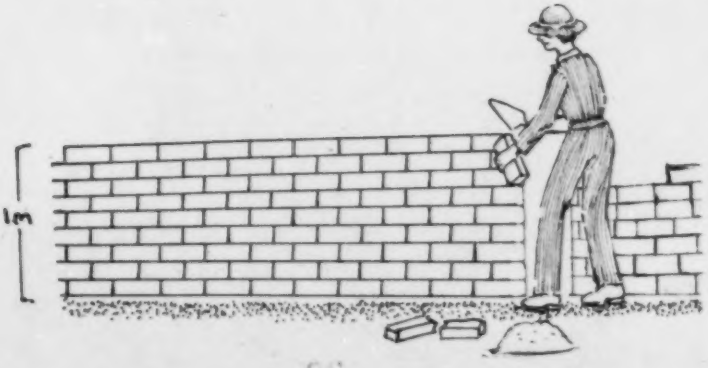


Have you ever realised that most of the work you do involved pulling, pushing or lifting things? Pushing, pulling and lifting things all require forces. Some kinds of work, like picking fruit and putting it into a basket require only a small force, but hard work, like lifting bags of maize requires a big force. The work will be harder if the bags have to be lifted higher. Have you noticed here again that the amount of work depends on two things. Can you name these two things?

Here are some puzzle pictures of people doing work.
Study these pictures carefully and then do
Exercise 9.







Since work or the energy needed to do it involves the force and the distance over which the force is used, we can measure work or energy by multiplying them together.

This can be written in short like this:

Work done or energy involved = force used x distance moved by force.

You remember we measure force in newtons (N) and distance we measure in metres (m). Work or energy can then be expressed like this:

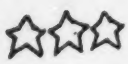
Work = force (N) x distance moved (m).

This can be shortened further like this:

Work or energy = N x m

This is the same as:

Work = Nm.



As you will notice the units in which work is measured are newton-metres (Nm). Scientists prefer to call newtonmetres by another name. They call them joules, often written like this: J .

Now calculate how much work each of the people in the puzzle picture has done. (Exercise 10)

Now you will do some work and measure it!

EXPERIMENT 14 : Measuring Work

You will need:

- a ruler
- a forcemeter
- a thread
- an empty match box
- some dry sand or soil

Before you begin copy the table your teacher has drawn into your exercise book .

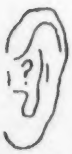
Empty your match box and fill it with sand. Now tie the box with a thread and hang the box on the forcemeter.

Hold the forcemeter at the other end and lift the match box slightly off your desktop. Note the force you have used to lift the match box just off the top of your desk. Now lift the box higher. What is the forcemeter reading now? Record this in your table too. How high above the table have you lifted the match box? Let your partner measure this height in metres. Record this in your table too. Now calculate the work you have done in joules.

Do not empty your match box yet, put it on one side of your desk, but remove the thread.

Now lift some more things using your forcemeter as you did with the matchbox. Please do not forget to complete the table each time you lift something. When you have completed your table answer Exercise 11.

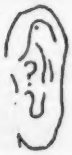
Tie your match box with a thread as you did before, and place it on your desk. Now use your forcemeter to drag the box slowly along the desk. Record this force and the distance you dragged the box in another table. Calculate how much work you have done.



Try measuring the work you do in moving other things about on your desk. Check if you can that the work you do is less if you reduce the frictional force. Discuss your results with your teacher.

MAKING WORK EASIER

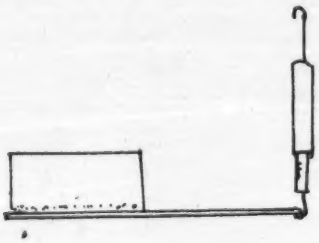
You have learnt about how forces are used to do work. You also learnt that some kinds of work need bigger forces than others. How much force do you think you use to push a door? Your teacher will let you push your classroom door in turns. Start by pushing the door near the hinges. Do you need a big force to do this? Then push the door again using the handle. Do you think you needed the same amount of force to push the door each time? From which position did you need to put more force to move the door? How did the force change as you changed the position of push?



Think carefully about the amount of work you did in each case. Your teacher will discuss this with you.

In which position was it <u>easiest</u> to push the door? Do you think the handle is the best place?

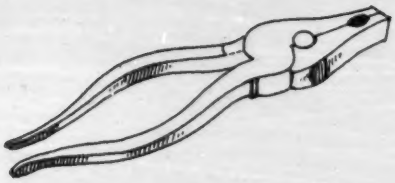
Take out your kit box and pour in three cups of sand. Spread the sand to cover the whole floor of the box. Lift your kit box using the ruler and forcemeter. Were you right in your answer to the problem?

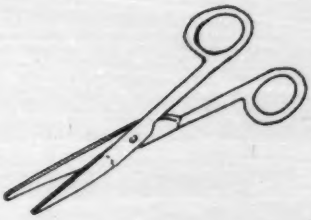


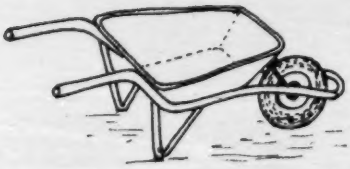
Now answer <u>Exercise 12</u> in your notebooks.

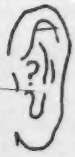
Did you notice that it was easiest to lift the box when you pulled near the end of the ruler with your forcemeter? You only used a small force when you pulled this way.

In your everyday life you have probably seen things which make it easy to move heavy loads. They make our work easy. Scientists call these things MACHINES. Some machines are simple like the ruler you used in lifting the kit box. Others have many parts like engines of cars. But most of the machines we use in our everyday lives are quite simple.





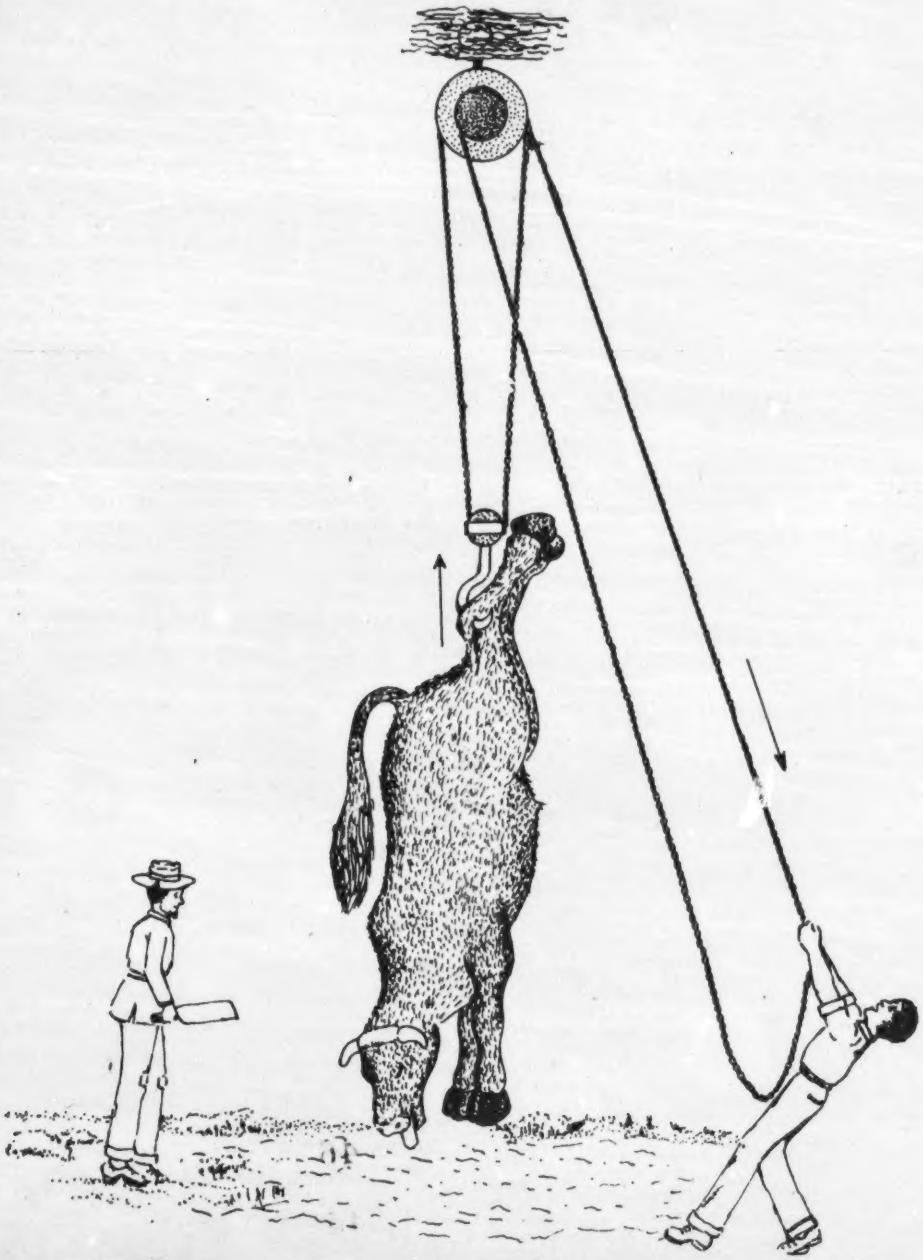




These pictures show some of the common simple machines. Think of some more simple machines, your teacher will make a list of them on the blackboard.

MORE ABOUT MACHINES

Here is another machine which is quite common. It is very unlikely that you have used a PULLEY SYSTEM yourself. It is most likely that you have seen a butcher using a pulley system to raise a dead ox before it is skinned.



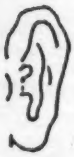
As you know, it would be very difficult for the butcher to raise a dead ox without help. A pulley system makes it possible for him to do so. You will now investigate how this machine works.

EXPERIMENT 15 : Investigating the pulley system

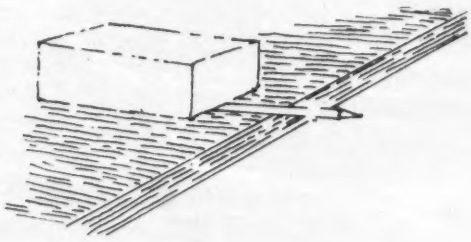
You will need:

- a ruler
- two sets of pulleys
- two pieces of thread
- a forcemeter
- your pencil or ball point pen
- a brick
- a torch battery
- plastic cup
- stones
- class balance

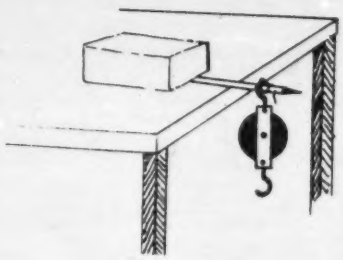
EXPERIMENT 15 Part 1



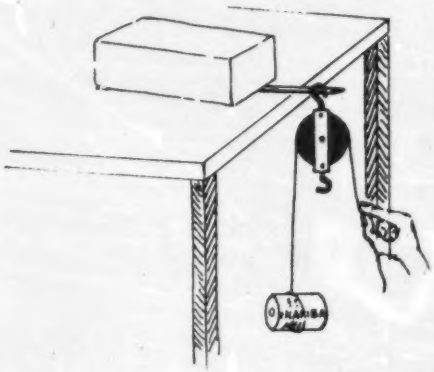
Your teacher will give you a small pulley. Look at it carefully with your partner. What is it made of? When you have finished looking, put it on one side on your desk. Now collect one brick from the pile of bricks. Place the brick near the edge of your desk and place your pencil or ball point pen under it as shown.



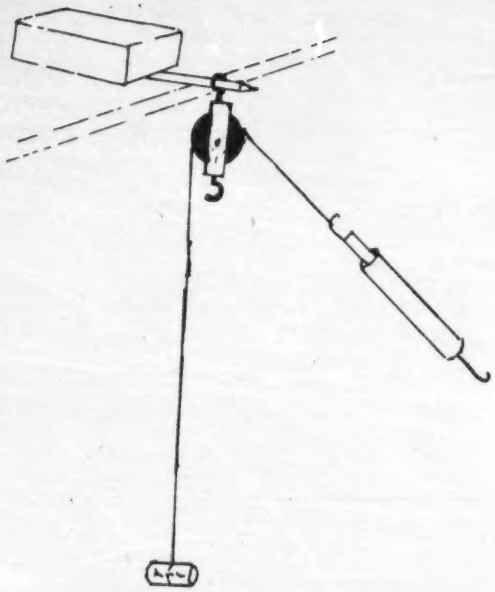
Tie the pulley onto the pencil so that the pulley hangs down at the edge of the desk.



Before you start, copy the table your teacher has drawn on the blackboard into your exercise book . Now collect one torch battery from your teacher. Find its weight in newtons. You wil_ .ave to think about how to do this. If you have not done so already, tie the battery with one end of the second thread. Put the other end of the thread through the pulley and hold this end of the thread.



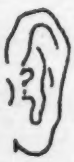
Now lift the battery by pulling the thread. How much force do you think you used to lift the battery? Was the force big or small? Do you think the pulley made it easier for you to lift the battery? Now tie the end of the thread you were holding onto the forcemeter and hold the forcemeter.



Pull on the forcemeter slightly to lift the battery off the floor. Hold the battery in this position and take the reading on the forcemeter. This reading is the force with which you are lifting the battery. Record this reading in your table.

Hold the forcemeter as shown in the diagram above again. This time you will need to measure the distance through which you pull the forcemeter. You will also need to measure the distance the battery has been lifted as you pull. Think very carefully about how you will do this before you start.

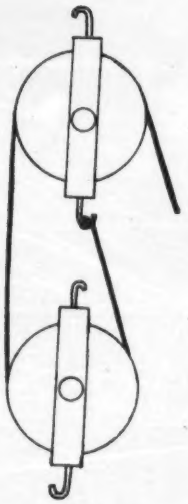
When you have measured both distances record the results in your table too. Then complete the rest of the table.



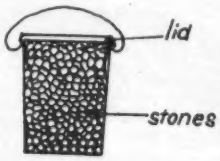
Your teacher will now discuss the completed table with you. After the discussion, you will lift things with more than one pulley this time.

Experiment 15 Part 2

Using More than One Pulley

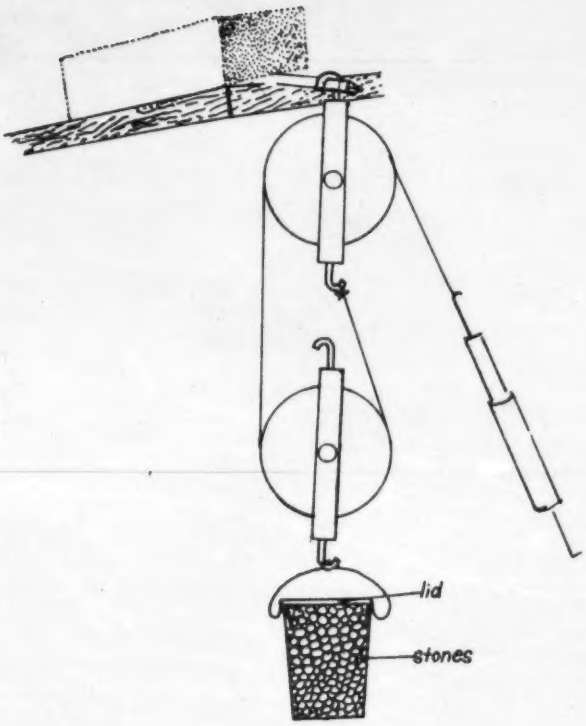


Study the diagram carefully and assemble your pulley system so that it looks the same as the one in the diagram. Put the table which your teacher has drawn on the blackboard into your notebook.



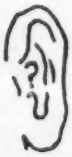
Add stones to your plastic cup until it has a total mass of 50g. (You can suspend the cup with a piece of string caught under the lid).

Now measure how much force is required to lift the cup using the pulley system.



Repeat the experiment with a load of 100 g and 150 g.

Complete all the columns in your table. Do the results surprise you? How much work was done on the load compared with the work which you actually did? Think carefully about the comparison between the measurements in columns 3 and 4, 5 and 6, and 7 and 8. Can you explain why a pulley system is a useful machine?

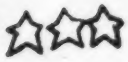


Discuss this question with your teacher.

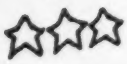
HOW POWERFUL ARE YOU?

In the discussion with your teacher you learned that a machine is useful because it allows you to work easily. Who do you think is more powerful, you or your partner? Perhaps you have now started looking at your partner to compare him with yourself. However, it is not easy to tell how much power your partner has just by looking at him. Maybe you need to know some things about him before you can tell. It is possible to investigate who is more powerful, you or your partner. If your teacher asked you both to dig two pieces of ground of the same size, the more powerful between you would finish the work first. That person would be doing the work faster.

A strong man may have big muscles which can generate a large force but unless he can use them quickly he is not powerful.



So when we talk about power we are talking about energy and time. You have learned that the unit of energy is the Joule and unit of time is the second. The unit of power is the joule per second.



This is given the special name WATT (James Watt was the one who invented the steam engine one of the first powerful machines).

A power of one watt means work is being done (and of course energy is being changed, at the rate of 1 joule every second).

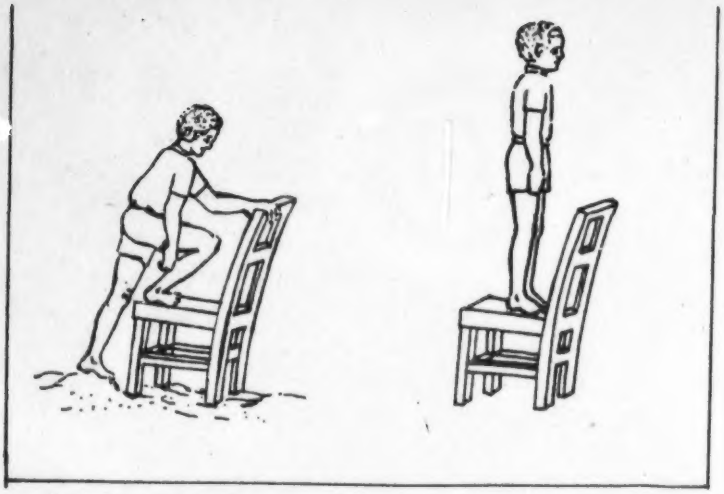
A million watts is called a Megawatt, and is written as MW

Experiment 16 : To Measure the Muscle Power in Your Legs

You will need : The Zim-Sci Clock
A chair or strong box

The picture shows a boy stepping up onto a chair and then stepping down again as if he is climbing stairs or a ladder.

Each time he steps up onto the box his leg muscles have done the work needed to lift his mass the vertical height of the box. Take turns with your partner to count how many times each of you can step up onto the chair and back down again in 30 seconds!



Now do exercise 13

Who is the most powerful person in your classroom?
Does the answer surprise you?

Discuss the results with your teacher.

To finish off this Unit, here is a table which shows the power of some common energy converters.

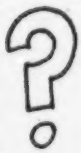
1.	Human being -short period of hard work	250 W
2.	Human being resting (chemical "food" energy to kinetic + heat)	100 W
3.	Cooking fire (chemical potential → heat + light).	5 kW
4.	Small motor car (chemical potential → heat + kinetic.)	50 kW
5.	Horse (working) (chemical (food) - heat + kinetic)	750 W
6.	Farm tractor ????	100 kW
7.	Bicycle dynamo (mechanical - electricity)	10 W
8.	Battery powered torch, (chemical → heat + light).	
9.	Transistor radio (chemical → sound + heat	0,2 MW
10.	Kariba Power Station ???	750 MW

Did you work out the energy chain for numbers (6) and (10)?

Remember these figures give energy conversion rates in joules per second. They do not say how long they can work at this power.

Eg. A man can only develop power of 250 W for a matter of minutes before he must stop to rest allowing his muscles to replace their "fuel supply" and get rid of the waste products produced in the muscles by the energy conversion process.

Now read and revise and do How much do you Know? Part III



How Much do you know? Part III

1. The amount of work depends on the _____ of an object and the distance it has to be moved.

2. Work is measured in _____.

3. Work = Force (N) x _____ (m)

4. I measured the work done when lifting a matchbox with a _____ _____ and a _ _____.

5. Some simple machines which make work easier are _____ _____ and _____, _____, _____.

6. 2 Pulleys make work _ _____ than 1 pulley does.

7. Power is measured in _____ and is work ÷ _____ .

8. _____ = 1 joule per second.

SUMMARY

1. A force is only observable when it is doing work.
   (Remember energy was only observed when it was changing from one kind to another.)

2. A force is the way by which energy transfers happen.

3. Forces are needed to move an object or to stop an object moving.

4. Forces act in a definite direction - up, down, sideways etc.

5. An object moves in the same direction as the force.

6. The greater the speed of an object, the greater the force needed to stop it.

7. The greater the mass of an object the greater the force needed to make it move.

8. Push and pull forces act in pairs in opposite directions. If they are equal they balance out. If they are unequal they do not balance.

9. A force may change the shape of an object.

10. An object which returns to its original shape after the force stops acting on it is said to be elastic or springy.

11. Gravity is the force with which the earth pulls on objects.

12. The weight of an object is the force with which the earth pulls on it.

13. The force of gravity is about 10 newtons per kilogram.

14. Gravity, magnetism and electricity are forces which act at a distance and can make things move without touching them.

15. Force can be measured with a forcemeter. A forcemeter contains a spring, and the amount by which the spring is stretched by known masses enables the forcemeter to be calibrated.

16. When two surfaces rub together a frictional force is produced Friction converts useful energy to waste heat and tends to stop things moving,

17. Friction can be reduced in machines by various methods.

18. Friction can be useful in helping to stop moving objects such as cars and bicycles.

19. The energy changed from one kind to another depends on the amount of work done.

20. Work done = force used x distance moved by force.
(or energy used)

21. The unit of work or energy is called the Joule.

22. Work can be made easier by machines.

23. Power is the rate at which energy is used or work done.

24. The unit of power is the joule per second, one joule per second is called a watt.

25. When a machine is used the amount of work done (or energy changed) is always more than if the machine was not used, but the power needed is smaller.

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